ANN. INST. GEOL. PUBL. HUNG. | vol. LXX. | Budapestini, 1987

Proceedings of the VIIIth RCMNS Congress

NEOGENE DYNAMICS OF THE PERI-TYRRHENIAN AREA IN AN ENSIALIC CONTEXT: PALAEOGEOGRAPHIC RECONSTRUCTION

by

M. Boccaletti, D. Cosentino, G. Deiana, R. Gelati, F. Lentini, F. Massari, G. Moratti, T. Pescatore, A. Porcu, G. Ricchetti, F. Ricci Lucchi and L. Tortorici

Introduction. A project on the palaeogeography of the peri-Mediterranean area has been developed in the frame of the Paleogeography and Geodynamics Working Group of RCMNS. Contributors to this project have been an Italian Group formed of researchers of the major Universities, of CNR and of the Italian Oil Company (AGIP).

The first results of the work done by the Group were presented at the Interim-Colloquium "Palaeogeography and Geodynamics of the peri-Tyrrhenian area" held in Florence in October 1984.

This paper reports on the synthesis of the research carried out so far, on the palaeogeography and geodynamics of the peri-Tyrrhenian segment, from the southern Alps up to Sicily.

This peri-Tyrrhenian segment is the most significant portion of the whole western Mediterranean, as it represents a connection between the Alpine—Dinaric and Maghrebid systems. Within this segment, the complex south Alpine—Apennines—Sicily orogenic system developed as a double orocline having the well-known S configuration.

The building of this system occurred in two major stages: a first, eo-Alpine, stage with a European polarity and a second, Apenninic Neogene stage, with an African polarity.

The latter discussed in this paper, is responsible for the formation of the S-like system, and it developed in a post-collisional ensialic context, starting from the Oligocene. This stage is characterized by the opening of the Ligurian basin up to the Burdigalian and, later on, by the opening of the Tyrrhenian basin (Boccaletti et al., 1982). All this process brought about important anti-clockwise rotations, with consequent outward migration of the compressional phases which are followed and overlapped by the tensional phases (progradation of the Tyrrhenian).

In this framework, the palaeogeographic reconstruction cannot be based solely on the present distribution of the sedimentary facies for the considered time intervals. It necessarily involves a palinspastic reconstruction which takes into account the contemporaneous processes of compression, tension and rotation. This entails the evaluation of various amounts of shortening and stretching (extension), both longitudinal and transversal to the chain axis. All this requires, besides a noticeable effort of synthesizing the knowledge so far achieved in various fields, to resort to a good measure of imagination.

The back area—thrust belt—foredeep system

Fig. 1 shows a schematic cross-section of the chain, from the external to the internal areas, where the following subdivisions were made:

— the foreland, including an emerged zone, formed by platform carbonates, and a submerged zone, where platform and basin deposits are recognized, with terrigenous—calcareous sedimentation, mainly pelagic and subordinately neritic. The foreland zones are connected with the foredeep through a slope, generally controlled by normal faults, and a ramp zone, which is difficult to define, and are dominated by hemipelagic sedimentation, with subordinate gravitational sediment flows;

— the foredeep develops between the base of the slope and the front-thrust of the chain. It is an asymmetric depression, with a strong subsidence and a complex physiography related to the compressional activity of the thrust zone progressing towards the exterior: the trough is filled essentially by turbiditic sediments. The initial sediment contributions from both sides of the trough. The facies are very diversified and refer to base-of-slope deposits, submarine fans and basin-plain deposits;

— the chain starts to be built up, in the Apennine area, in Upper Oligocene. The chain front allows a discontinuous migration from the interior towards the exterior, until its present position in the Adriatic. In the tectogenetic events important stages of crisis (acmes?) are recognized. Some of these appear ascribable to mechanical response to, for instance, different crustal thickness of the foreland rather than to general variations of the thrust induced by the convergence of the two main, African and European blocks.

Discontinuous basins (piggybacks) develop within the thrust belt, which is their main sediment source. The sedimentation in these basins is clastic, generally coarse and even discontinuous.

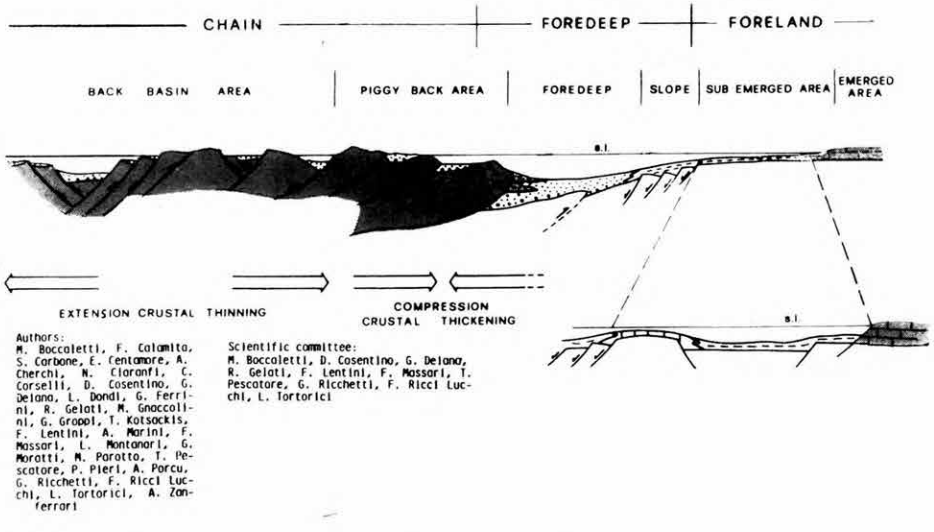

Fig. 1. Schematic cross-section of the chain from the internal to the external areas, with the attribution of the various basins to different structural zones

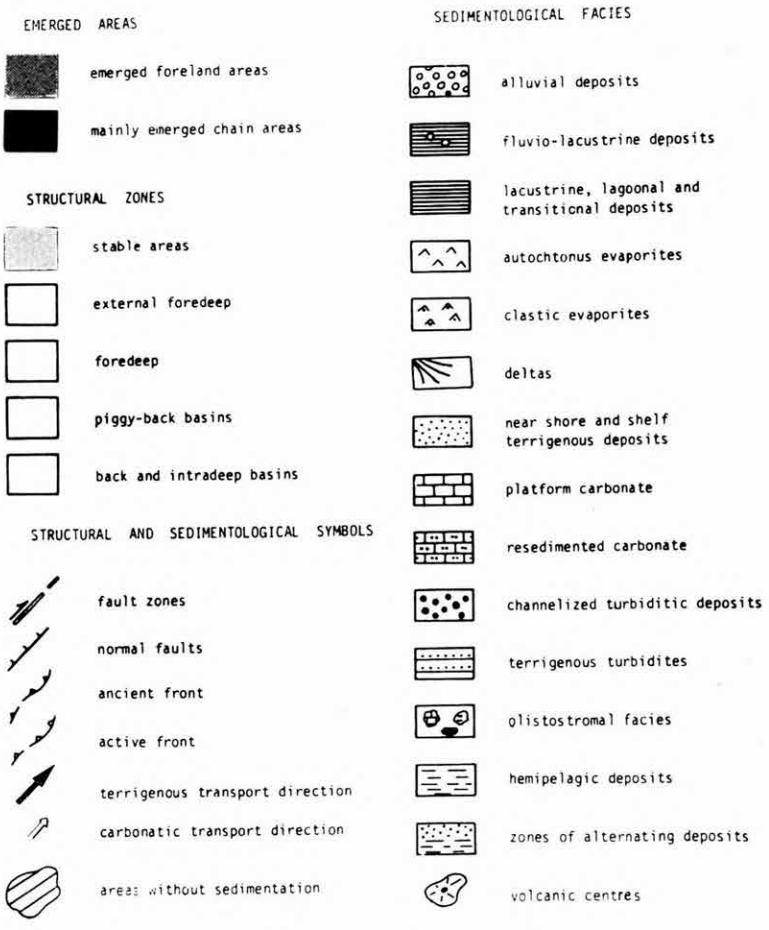

Fig. 2. See caption of Figs. 3—9

In the inner part of the chain, a tensional regime replaces the previous compressional regime producing the fragmentation of the thrust belt up to its destruction. This is caused by a process of stretching and crustal thinning. In this area, intrachain basins (back basin and intradeep) develop, grading from continental to marine.

Within the sedimentation areas the main facies are shown, as subdivided on the palaeogeographic maps (Fig. 2).

Palinspastic and palaeogeographic reconstructions

The maps, prepared according to the previously mentioned criteria, represent the present-day distribution of the sedimentary facies referred to the following time intervals: Upper Oligocene (25 m.y.), Burdigalian (20—22 m.y.), Langhian (16—17 m.y.), Serravallian (13—15 m.y.), Tortonian (9—10 m.y.), Late Messinian (5.3—5.5 m.y.), Early Pliocene (4 m.y.).

These maps represent only a starting point for the palaeogeographic reconstructions. For this purpose, the amount of shortening of the external thrusts was evaluated through balanced cross-sections (see also BOCCALETTI, these volume). The values so obtained were employed as minimum orders of magnitude to assess the shortening in the internal zones. Furthermore, for each considered interval, an overall balance was attempted, between the total shortening and the total extension of the internal zones, assuming crustal values, before and after the extension, based on the present data.

The total displacement of the fronts, between Upper Oligocene and Lower Pliocene is approximately reckonable as 250 km in central northern Apennines, and as much as 600 km in the Calabrian arc.

Upper Oligocene

The Upper Oligocene marks the beginning of the Apenninic–Maghrebid tectogenesis, i.e. the birth of the chain sensu strictu (Fig. 3). During this period, Corsica and Sardinia are still in crustal continuity with the European continent. The

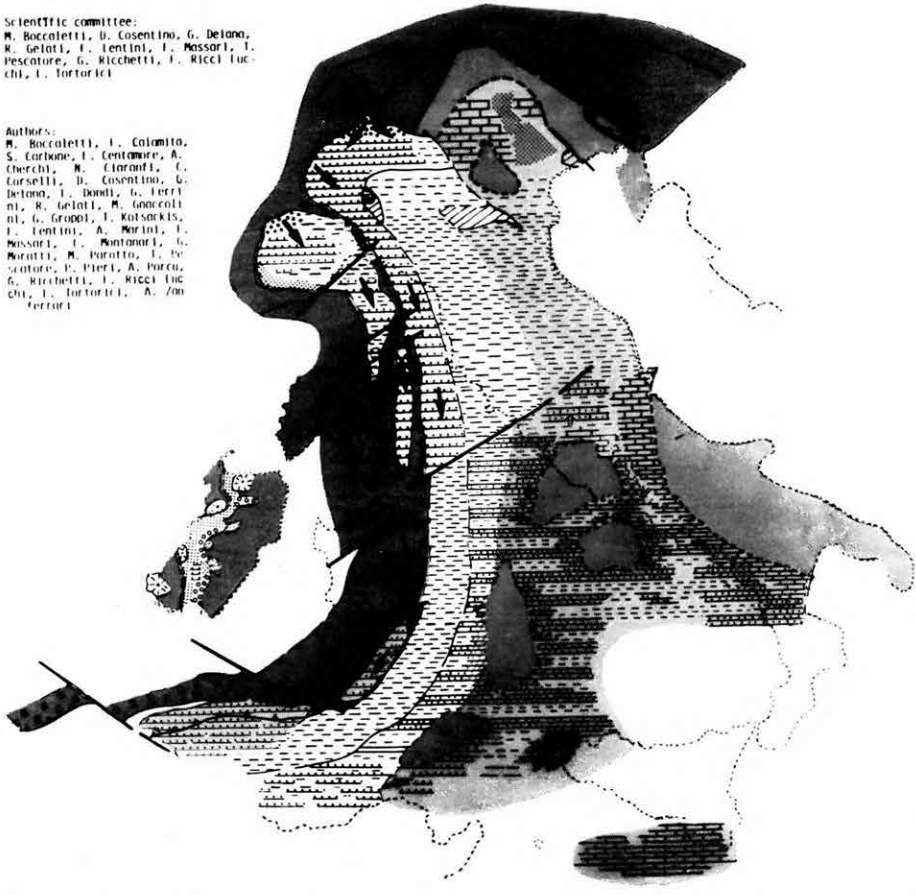

Fig. 3. Palaeogeographic reconstruction during Upper Oligocene (25 m.y.)

oceanization phase, which will set in at 23/24 Ma, has not yet begun, and the stage is still that of preoceanization rifting.

Corsica and Sardinia assume the role of hinterland with respect to the Apenninic system. Previously, in fact (Cretaceous—Eocene phases), they were part of the foredeep of the eo-Alpine chain.

The corrugated chain is included between the eo-Alpine fronts, already inactive, to the west, and the active Apenninic fronts, to the east.

On the active thrust belt some piggyback basins start developing, namely, from north to south: the Ligurian—Piedmont basin, the Ranzano basin, the basin of the Coastal Macigno, all with longitudinal sediment contributions. Towards the south, the Cilento basin and part of the Numidian flysch basin are forming. For what concerns the foredeep, the Macigno turbidites develop in the northern segment, with longitudinal sediment flow from the central western Alps. These turbidites stop abruptly in correspondence to the Grosseto—Chienti line (GCL). To the south, the deposits are pelitic and become arenaceous in the southernmost part (Numidian flysch).

The difference between the northern and the southern segments exists also on the slope. In fact, in the north, pelites prevail over calcarenites, whilst, in the south, turbiditic calcarenites are more frequently encountered.

More externally (foreland), north of the Grosseto—Chienti line, hemipelagic sedimentation continues. South of the mentioned line, basins with pelagic sedimentation develop. They are interposed amid neritic carbonate platforms, partially emerged at that time. The platforms feed clastic carbonate material to the basins and to the adjacent slope (white arrows).

Carbonate platforms develop also in the south Alpine segment. In the western south Alpine the occurrence of southward translations controls the entry-points of turbidites, while in the eastern part such movements are lacking during the time-span in question.

Burdigalian (22—20 m.y.) (Fig. 4)

In this interval, the translation of Corsica and Sardinia has already occurred, but the whole 30° rotation of Sardinia is not yet complete. Therefore, there is an increase, in the emerged areas, of the zones under stretching, with the formation of back-arc basins: Sardinia, Corsica and Finale Ligure basins.

An eastward migration of the external fronts follows, with also an increase of their curvature.

In the foredeep, siliciclastic, turbiditic sedimentation prevails. It is represented in the north by the Cervarola flysch, which is interrupted towards the south at the Grosseto—Chienti line. In the south the foredeep is filled by the quartz-arenitic Numidian flysch of African origin, which abruptly ends, northwards, at the Gaeta—Gargano line.

The Grosseto—Chienti line still separates the northern and southern segments; a mainly pelagic sedimentation continues in the north, both in the slope and in the foreland. To the south, where the Panormide and Campania platforms are already involved in the tectogenesis, the slope and the foreland areas are still influenced by the presence of neritic carbonate platforms, which continue feeding the adjacent basins with clastic material.

In the south Alpine area, the thrusts are still active in the western segment, but show a tendency to migrate towards the east, as indicated by the eastward migration of the entry-points of the turbidites, which feed the Cervarola formation in the foredeep.

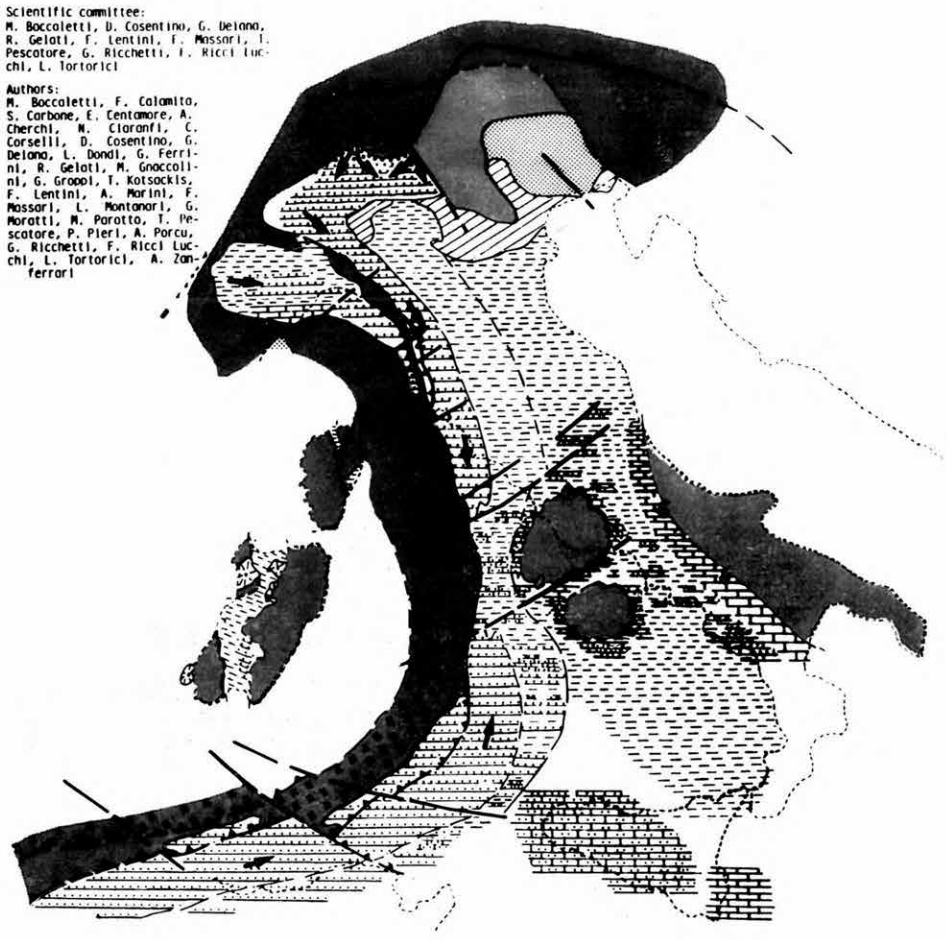

Fig. 4. Palaeogeographic reconstruction during Burdigalian (20—22 m.y.)

The eastern segment is quieter and is dominated by a broad platform area partly emerged and partly the site of glauconitic sandstone deposition.

Langhian (16—17 m.y.) (Fig. 5)

During the Langhian, the translation and rotation of Corsica and Sardinia are completed. This time represents an important palaeogeographic stage. It is characterized, in fact, by an extensive "transgressive" phase, revealed by a general tendency of the carbonate platforms to be drowned. An increase in frequency of carbonatic and hybrid mega-turbidites in the foredeep is noticed. This would suggest an underwater tectono-seismic (?) dismantlement of the platforms.

The Grosseto—Chienti transversal bundle still separates two major northern and southern segments. These, in turn, are further subdivided by other transversal lines. To the north, in the Apennines, the NE—SW transversal lines prevail, of which

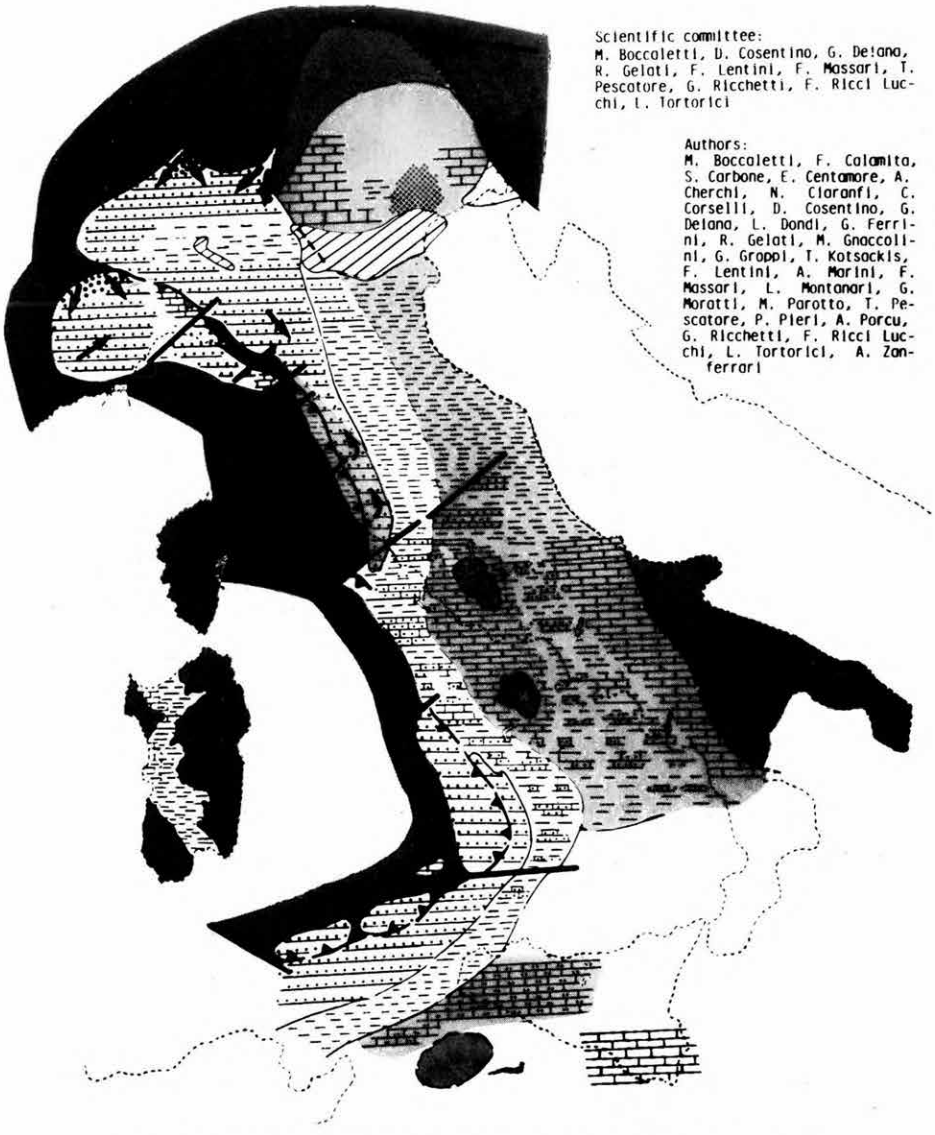

Fig. 5. Palaeogeographic reconstruction during Langhian (16—17 m.y.)

the Ligurian bundle, the Livorno—Sillaro and the Piombino—Faenza lines are the most conspicuous.

In the south Alpine unit, the NW—SE transversal lineaments are more frequent. Of these, the bundle approximately located on the Verona—Legnago alignment is the most important. This lineament acts as eastern limit of the thrusts and of the foredeep zones. To the east, in fact, the area is still quiet, with carbonate deposition, although the submerged area appears increased with respect to the Burdigalian interval.

To the south, the dominant transversal lineaments are oriented E—W (South Tyrrhenian system) or NW—SE (Ligurian—Balearic basin system).

Noticeable changes occur concerning the piggyback basins. The facies become more pelitic (Marne di Cessole, etc) and new basins are forming: Vicchio marls, Gorgoglione flysch, Capo d'Orlando flysch.

In the foredeep, turbiditic sedimentation continues: Marnoso—Arenacea in the north, Numidian flysch and Serra Palazzo flysch in the south. The clastic contributions related to the transversal accidents become important in the Marnoso-Arenacea. Still in the Marnoso-Arenacea, minimum deposition rates are observed, which confirm the transgressive tendency noticed at large. An important difference between the northern and the southern segments, is the further accentuation of the arching of the southern sector of the corrugated belt. This fact may be related to the 30° rotation of Sardinia, relative to Corsica, which ended 19 Ma BP, and possibly to the beginning of rifting in the Tyrrhenian.

Serravallian (13—15 m.y.) (Fig 6)

In this interval, a further transgressive tendency occurs. This is shown by the complete drowning of the southern platforms and by the deposition of some flysch, both in the foredeep and in piggy-back basins. In the north, in fact, both the Marnoso—Arenacea and the Bismantova show minimum rates of sedimentation, which are, however, compensated by regional tectonic events. In fact, in this period, the generalized transgression is accompanied by an important and strong deformational phase.

The Grosseto—Chienti line still separates two areas, to the north and to the south, with different evolution. The northern segment shows noticeable variations of shape and facies concerning the piggy-back basins. A higher segmentation and consequent isolation of the basins occur, in correspondence with the transversal lines. Along some of the latter, conditions of a "high" occur with platform deposits, which are brought into direct contact with the basinal turbidites. The influence of the transversal lines results also in important transversal sediment contributions to the foredeep.

Another major difference, with respect to the Langhian, is found in the south Alpine, where important thrusts affect the eastern segment, so far stable. This fact is accompanied by the fragmentation of the existing platform and the onset of piggyback and foredeep areas with terrigenous sedimentation. The fragmentation is controlled by important transversal lines belonging to the Schio-Vicenza and Giudicarie systems. These lines show also transcurrent movements.

In the southern segment the most important event is the complete drowning of the foreland carbonate platforms, as previously mentioned. In the foredeep, the quartz-arenitic sedimentation of African origin of the Numidian flysch is definitely replaced by pelites (shales) and arcosic sandstones.

The arching of the southern thrust belt is still more marked and it already foreshadows the destination of the wouldbe Calabrian arc.

The accentuation of the arching is guided by an important E—W transversal accident (south Tyrrhenian bundle) and is, in our opinion, related to the incipient opening of the south Tyrrhenian (basin).

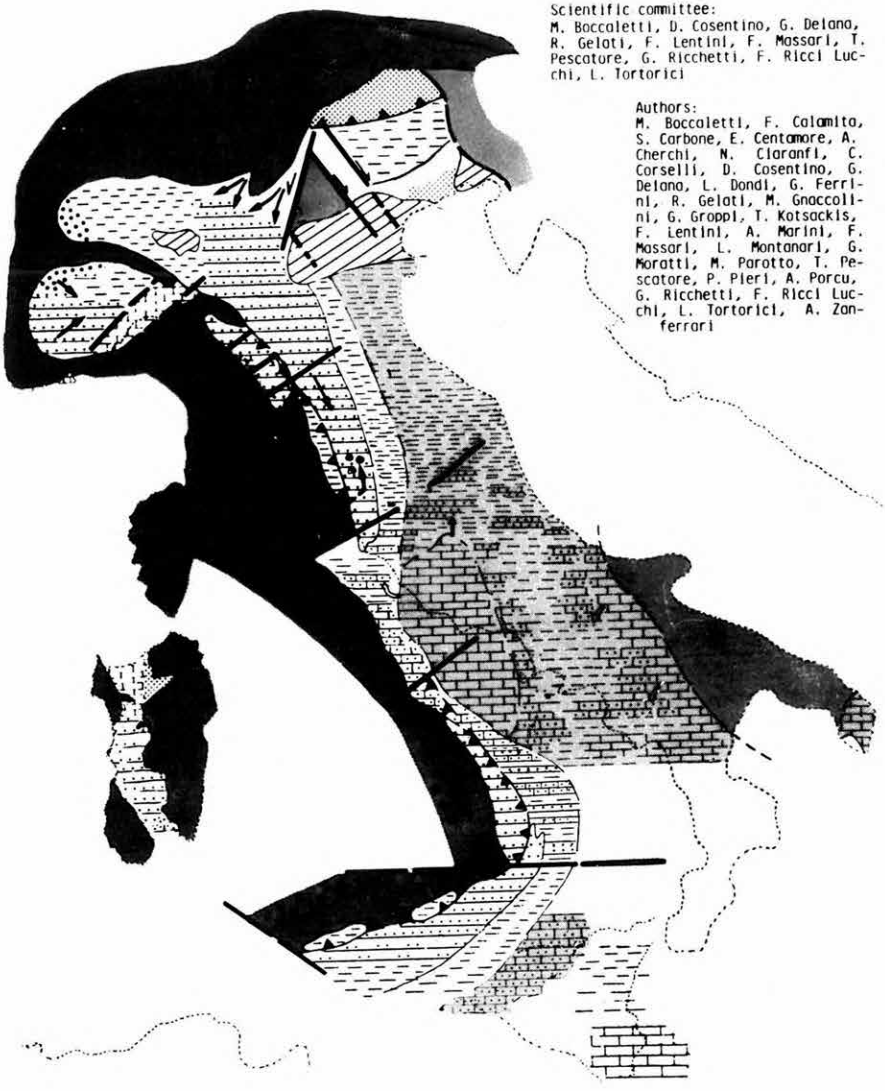

Fig. 6. Palaeogeographic reconstruction during Serravallian (13—15 m.y.)

Tortonian (9—10 m.y.) (Fig. 7)

This period is characterized by noticeable palaeogeographic changes related to a generalized major tectonic phase.

Large portions of the foreland, so far stable and characterized by platform deposits and intra-platform basins, are reached by the slope and foredeep zones, where sedimentation is mainly terrigenous, fine or coarse.

Even the Latium—Abruzzi carbonate platform is destroyed and replaced by a complex foredeep with turbiditic deposits confined to narrow longitudinal basins (Livi and Sacco basins).

The central southern segment shows the most striking physiographic changes with respect to the previous time-span. The first back-arc basins appear in the Calabrian arc zone, already reached by the extension following the futher opening of the Tyrrhenian (already realised more to the west, Cornaglia basin). Still in the Calabrian arc, portions of the eo-Alpine chain have proceeded eastward in respect to the slope and ramp-foreland areas.

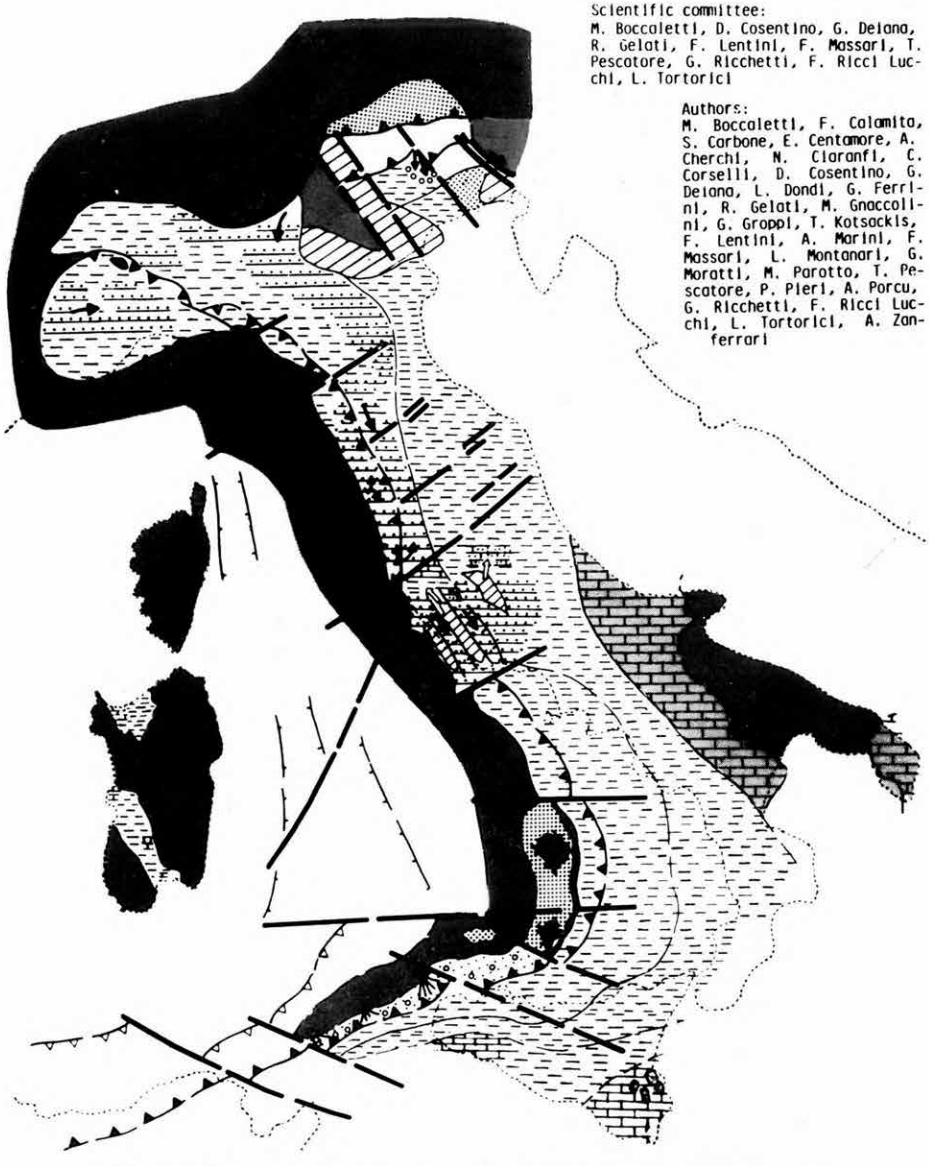

Fig. 7. Palaeogeographic reconstruction during Tortonian (9—10 m.y.)

In the south Alpine segment, a southward migration of the thrust fronts is noticed. These fronts, however dissected, appear by the Schio—Vicenza trend, which affects the area unto its easternmost part near the Dinarides. Especially in correspondence with the lineaments of this trend, the entry-points of terrigenous, generally coarse, deposits, are located.

Late Messinian (5.3—5.5 m.y.) (Fig. 8)

This interval follows immediately the salinity crisis. Two segments, separated this time by the transversal Gaeta—Gargano line, become well individuated.

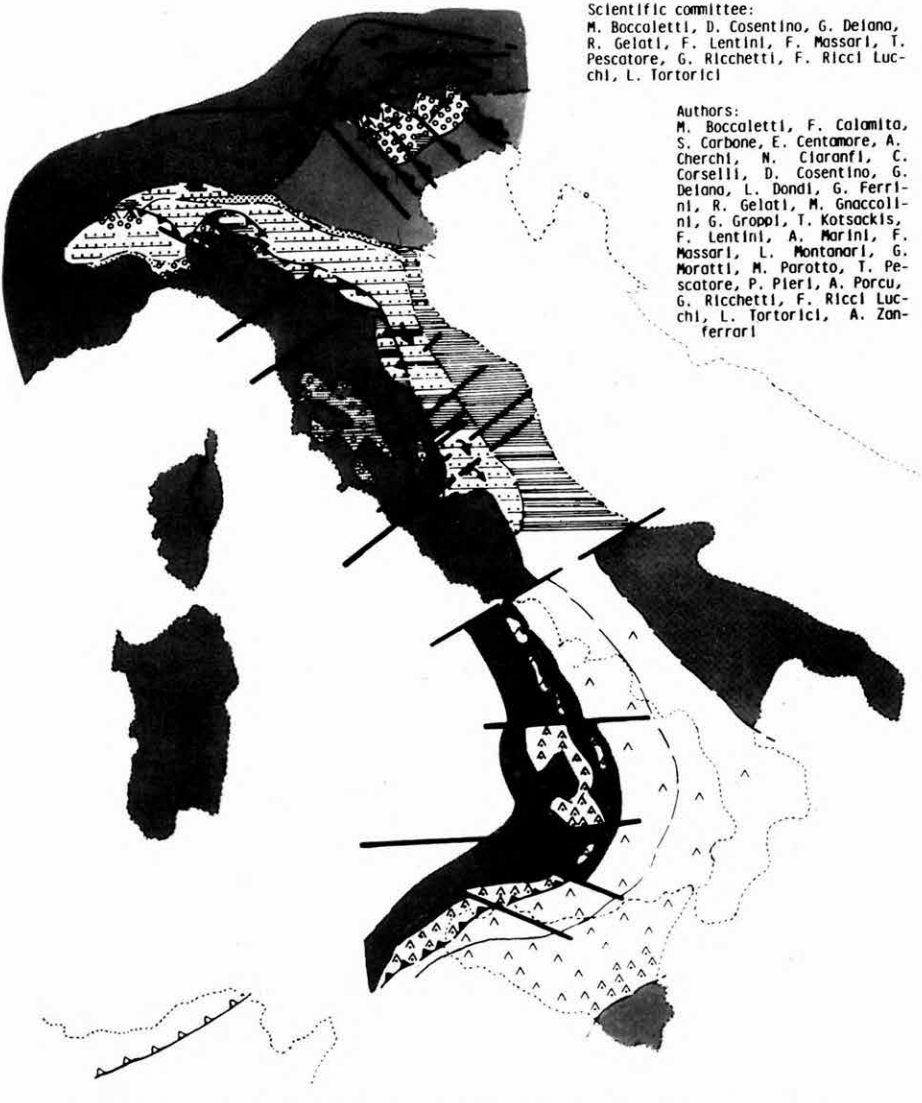

Fig. 8. Palaeogeographic reconstruction during Late Messinian (5.3—5.5 m.y.)

North of this line the evaporitic cycle is present only in the back-arc areas, to the north of the Piombino—Faenza line. In the foredeep and foreland it is replaced by prevalently pelitic (Colombacci Shale) or turbiditic (Laga and Fusignano Formations) successions.

South of the Gaeta—Gargano line, another evaporitic cycle can be recognized (Upper Evaporites). It lies above the previous evaporitic cycle in almost all the structural zones. The evaporitic deposits are primary or resedimented. In this area the distinction of the structural zones on the basis of the sedimentary facies remains therefore difficult.

The Gaeta—Gargano line, thus, results as an important barrier that separates, in the internal areas, two different worlds of problematic interpretation. Probably, among the principal causes of this are: the presence, to the north, of the Alpine chain, supplier of great quantities of water; and a greater supply, especially transversal, tied to an intra-Messinian tectonic activity, as it has been recently shown.

In the Po plain and Adriatic foredeep the molassic stage begins, sometimes unconformably on the underlying evaporites. The unconformity is widespread in the piggy-back areas, which are now reduced and mainly have fan-conglomerate sedimentation. In the back-basin basins of internal Tuscany, continental deposits overly the previous evaporitic and marine sediments.

In the south Alpine unit a foredeep, with pronounced subsidence, filled with fan-like coarse sediments, develops, in correspondence with the external thrust fronts, which are confined to the eastern part.

Early Pliocene (4 m.y.) (Fig. 9)

In the early Pliocene, a new, widespread and important tectonic event initiates. This produces extended palaeogeographic variations, as a consequence of the higher continuity of the structural zones, longitudinally, from north to south, even though a transversal segmentation of these zones is still evident, especially in the internal areas.

The chain approaches its definite shape, with the external thrusts fronts near their present position. The foredeep develops in continuity from the Po Plain southwards, up to the Adriatic area, the present-day Bradanic trough and the Hyblean foreland. In the Calabrian arc, the internal areas, together with fragments of the eo-Alpine chain, have proceeded towards E and SE along transversal tracks oriented NW—SE and E—W.

The Pliocene tectogenetic event is characterized, with respect to the Miocene events, by an evident and generalized jump of the frontal thrusts. Concurrently, the most important marine ingression occurs in the internal areas, with extended back-arc basin development. Although these back-arc basins seem longitudinally continuous, they are instead segmented by transversal lines, thus resulting in an articulated and complex physiography. This results from a strengthening of the tensional processes, tied to the opening of the Tyrrhenian sea, prograding eastward.

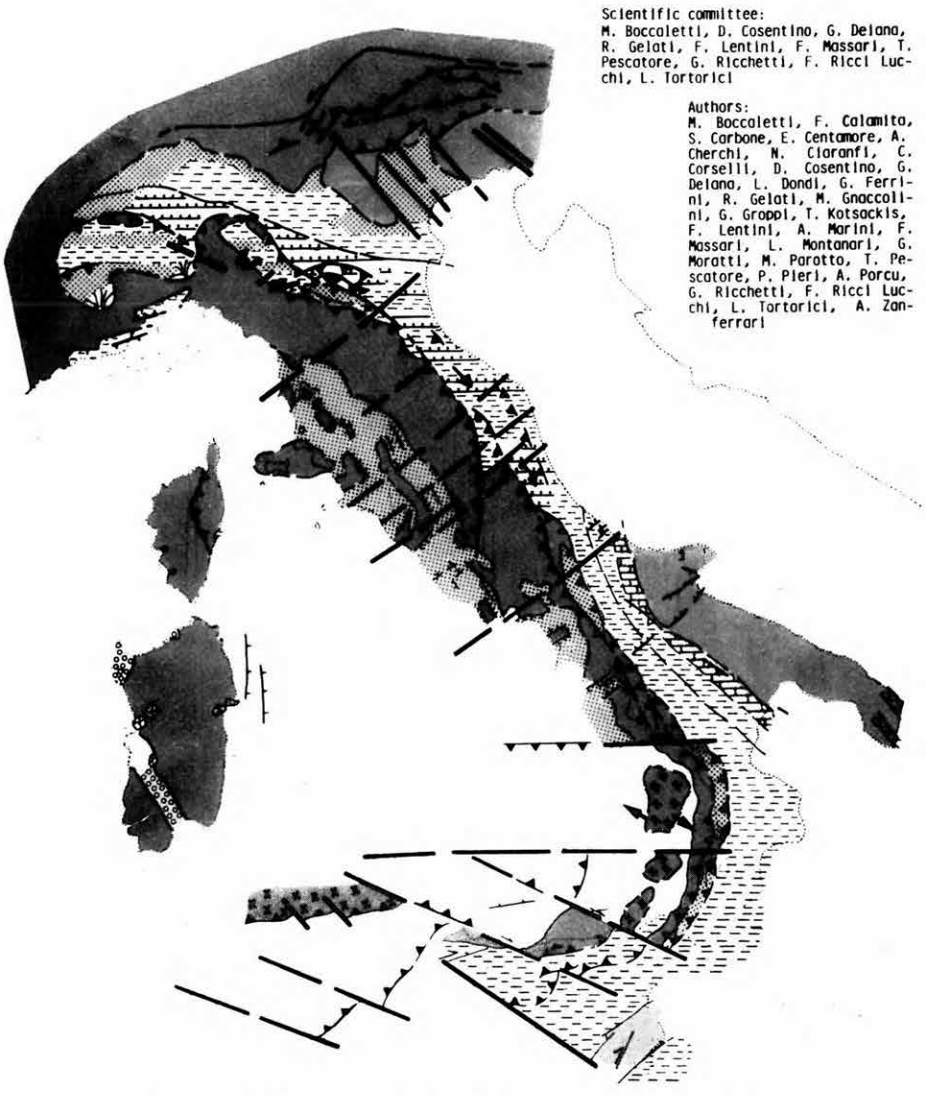

Fig. 9. Palaeogeographic reconstruction during Early Pliocene (4 m.y.)

Concluding remarks

The comparative analysis of the various time intervals considered allows to draw some general conclusions.

Four moments of primary importance can be clearly singled out, during which considerable geodynamic and palaeogeographic modifications occur in the whole peri-Tyrrhenian area:

1 The late Oligocene is the first important stage, in which the actual tectogenesys of the Apennines and Maghrebids initiates. It occurs simultaneously with the beginning of rifting in the Ligurian—Provençal zones.

2 The second stage delast from the late Burdigalian till the early Langhian. There is a significant migration of the external fronts, especially with the rotation of the Sardinia block. Possibly these events are already related to the beginning of rifting in the Tyrrhenian sea.

3 The third stage occurs in the Tortonian, with the well-known tectonic phase developed throughout the Apennines. It results in a better identification of the southern arc, definitely more advanced than the northern arc. This fact is to be related to a greater extensional process affecting the southern Tyrrhenian, with respect to the northern part.

4 Finally, the fourth stage develops between the end of the Lower Pliocene and the base of the Middle Pliocene. There is a generalized jump of all the fronts towards the exterior. Particularly, there is a better identification of the various segments of the Calabrian arc. The northern segment of the arc has proceeded towards the east, guided along a transversal bundle oriented E—W. This bundle bounds to the south the extension of the Tyrrhenian.

Two other events, generalized throughout the area, of palaeogeographic rather than tectonic importance, are referable to the Langhian and Serravallian. The tectonic events are, in these periods, associated with a widespread transgression, witnessed by an increase in marly—pelitic sedimentation, by the complete drowning of the carbonate platforms and by a minimum in the rate of sedimentation of turbidites in the foredeep.

In any case, the geodynamic evolution of the whole area seems to be clearly controlled by the activity of major bundles of tectonic lines, transversal to the chain.

The most important of these bundles have a different orientation according to the various segments of the chain: NW—SE (south Alpine), NE—SW (northern central Apennines), NW—SE and E—W (southern Apennines and Sicily). They determine a different dynamic behaviour from segment to segment, as well as they influence the facies distribution, representing, in some moments, preferential channelways for the turbiditic flows. The most important of these lines are:

— the Ligurian line that releases the fulcrum zone for the anticlockwise rotation of the northern Apennines;

— the Grosseto—Chienti line. It allows an independent evolution of the northern Apennine with respect to the southern Apennines, often impeding the basins;

— the Gaeta—Gargano, which allows an independent evolution of the Calabrian arc with respect to the central Apennines;

— lastly, the south Tyrrhenian line, of E—W orientation. It forms the southern limit of the Tyrrhenian opening, and also allows Calabria to migrate towards the east with respect to the contiguous Maghrebid area.

The role that each line played in time and space is nevertheless complex. During the same phase, in fact, they act in the outernmost part of the thrust belt as lines separating fronts with different entity of advancement, to which different values of shortening correspond. In other parts, the same lines separate totally different facies, showing vertical movement components. In the most internal areas, they even separate

segments having a different amount of extension. In any case these tectonic lines certainly have a crustal, or even deeper, significance; they might have acted along pre-Neogene, or even pre-Alpine discontinuities.

M. BOCCALETTI
Dipartimento di Scienze della Terra
Via G. La Pira 4
50121 FIRENZE

D. COSENTINO
Dipartimento di Scienze della Terra
Universià "La Sapienza"
Piazzale A. Moro 5
00185 ROMA

G. DEIANA
Dipartimento di Scienze della Terra
Via E. Betti 1/A
62032 CAMERINO (Macerata)

R. GELATI
Dipartimento di Scienze della Terra
Via Mangiagalli 34
20133 MILANO

F. LENTINI
Istituto di Geologia
Corso Italia 55
95129 CATANIA

F. MASSARI
Istituto di Geologia e Paleontologia
Via Giotto 20
35100 PADOVA

G. MORATTI
Centro di Studio per la Geologia
dell'Appennino in rapporto alle
geosinclinali mediterranee.
C.N.R.
Via G. La Pira 4
50121 FIRENZE

T. PESCATORE
Dipartimento di Scienze della Terra
Largo S. Marcellino 10
80138 NAPOLI

A. PORCU
Istituto di Geologia
Sa Duchessa
09100 CAGLIARI

G. RICCHETTI
Dipartimento di Geologia e Geofisica
Palazzo Ateneo
Via Nicolai 2
70100 BARI

F. RICCI LUCCHI
Istituto di Geologia
Via Zamboni 63
40125 BOLOGNA

L. TORTORICI
Dipartimento di Scienze della Terra
Universià della Calabria
87030 CASTIGLIONE COSENTINO
SCALO (Cosenza)